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PHYSICS IN THE SECONDARY SCHOOL.*

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Physics should receive much greater attention than is now accorded it by the manufacturers of secondary school curricula. This because of its value for training, for culture, for ethical instruction.

Trite though it be to say it, I conceive that the most important function of any instruction at the secondary school age must be to prepare the instructed for future usefulness and happiness, *i. e.*, for best citizenship.

While the character and personality of the teacher are of prime importance in this preparatory work, the subject matter taught and the method of teaching are of only less moment.

Physics, by virtue of the character of its subject matter and more especially because of the method of treatment appropriate for those portions of it which are of secondary school grade, furnishes material and method valuable in the preparation for "complete living."

The teacher of physics should no more allow himself to forget this phase of his work than does the teacher of history or literature. He is primarily engaged in helping to prepare young men and young women for life, secondarily in teaching his subject.

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So much, in passing, with reference to some of the more general and larger questions with which physics teaching in secondary school is directly or indirectly connected; my chief concern at present is with the more limited question of matter and methods of instruction in the subject itself.

This brings me at once to the consideration of the laboratory, for I believe the equipment and use of the laboratory to be the most important factor in the work; and I consider this to be true for the instruction of pupils fresh from the elementary school at twelve or thirteen years of age, as well as for those of eighteen in their senior year—true for students who are preparing to meet examinations for admission to college or scientific school, true for those who are studying physics as a part of a general education and for those who take it because it chances to be in the course—true for the boy who studies physics only one year as well as for those who are permitted to continue the subject through a large part of the secondary school course.

The time allotment for the subject should be such that the pupil may have laboratory practice, numerical problems, recitations and lectures. The share of time devoted to each of the four will be dependent somewhat upon the age and maturity of the class. In general, the younger the pupils the larger the proportion of time spent in the laboratory, more time being needed for the discussion and assimilation of a single experiment as well as a greater variety of experiments bearing on a single subject.

Except in case of boys of unusual natural qualifications or those who are in the last year of a stiff high school program, laboratory work should not be in the nature of a course on physical measurements.

I would hardly even mention significant figures and would place slight emphasis on percentage of error; nor should we go to the opposite extreme of giving simple qualitative experiments which merely illustrate—if they illustrate anything—principles with which the twelve-year-old boy has for some time been more or less familiar.

It is undesirable to insult the intelligence of the boy even though he may not be able to return the compliment.

The following is an example of an experiment of the sort referred to, recently in use in some quarters, I believe:

Exp. Carefully examine your pencil. Drop it on the floor. Pick it up. Has it suffered any change?

We select, rather, for the pupils' laboratory work fundamental experiments which are quantitative in character and demand care, skill and strict attention on the part of the worker, yet are not beyond his ability—there are plenty of such.

The place for the purely qualitative, illustrative, experiment is the teacher's lecture or the demonstrative table.

In the actual arrangement of laboratory work we believe in and practice the duplication of apparatus, in case of most experiments, to equal the number of workers in a class, especially emphasizing this with the younger sections.

This means working always with practically an even front and giving all the members of a class the benefit of all discussions which follow the laboratory exercise. We have no more use for the rotative plan than for the crazy quilt or the patchwork of the New England grandmothers.

We supplement laboratory work with numerical problems—not too difficult—for the purpose of clarifying pupils' ideas and aiding in fixing the principles involved in the laboratory exercises. Incidentally these problems furnish a practical and satisfactory basis for correlation with elementary mathematics—a subject on which much yet remains to be said and done.

The lecture arouses interest and enthusiasm and helps to vitalize and humanize the subject. Designedly following, chronologically, the other phases of the work, one of its most important features is the treatment of the practical application of the principles already dealt with in laboratory and quiz.

When the boy has an elementary knowledge of the principles involved it is of some value to him to see the wheels go 'round—of very little use without this knowledge. Further, the continuous performance at a variety show costs less money in the end.

When he knows the principle of conjugate foci he is ready to properly appreciate the magic of the lantern. When he has fully learned that steam does work, falls in temperature, loses energy in

expanding against pressure, the steam engine is something more than the plaything of an hour.

He must take his sweets as dessert, not before meat.

I have briefly outlined some of the matter and the methods which we employ and believe in employing in the school which I represent. Throughout the course we try to avoid two extremes—one that of making the subject too scientific, the other the too utilitarian point of view.

We do not wish to make physics like the theory of numbers—the favorite subject of a certain mathematician because, as he said, "It has never been prostituted to any practical use." Nor do we care to have the pupil mistake the laboratory for a toyshop.

A satisfactory foundation is laid for later college work in the subject and excellent preparation given those whose formal education ends with the secondary school.

I believe I shall be well within the limits of the truth if I say that in my city the powers that be, educationally speaking, are convinced that the more than two hundred pupils who study physics in the high school are satisfactorily employing their time and justifying the use of the five thousand square feet of floor space given over to their work.

If these people are correct in their views it is because the laboratory is an instrument for training in the highest types of honesty; because the course gives greater breadth of view and a better attitude toward life; because the pupils are trained to think and to do.

ADJUSTMENT OF HIGH SCHOOL COURSES IN PHYSICS TO MEET THE INCREASED SCOPE OF ELEMENTARY PHYSICS.

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Physics, like other sciences, has in recent years greatly increased its scope. Whole subjects, such as wireless telegraphy, X-rays, the phonograph, theories of solution, liquefaction of gases and spectroscopy, have been added by the discovery of new principles. Old principles have acquired greater application and the

water wheel, the dynamos, the motor, the storage battery, the transformer and the electric lamp constitute a body of knowledge as extensive as all the other subjects of physics combined.

In view of the fact that all of this knowledge can not be satisfactorily covered in a high school course in physics, and yet that it is desirable to cover as much of it as possible, the questions arise, what conditions or factors may serve as guides in the determination of such a course (or in the selection of the subject matter of such a course)? Moreover, we may well ask, what constitutes elementary high school physics? What we, ten years ago, called an elementary high school course in physics now would seem incomplete and inadequate for our present progress and needs. The addition or material change of some subject is almost a biennial occurrence. We seem, in fact, to be confronted with the problem that elementary high school physics is rapidly progressing, while the student's ability to learn and the teacher's power to impart knowledge are but slowly advancing to keep pace with it. We may believe that it is not necessary that elementary high school physics should keep up with the progress of physics; that as the scope of physics increases, so the student and teacher increases in power to deal with the subject. Whatever view is taken of the matter, we have a real problem which demands attention and thought.

Of first importance in deciding what shall constitute the subject matter of an elementary high school course in physics is doubtless the question of adaptation to age, mental attainments, previous preparation, time and equipment for work.

Ordinarily, the older a student is the better he is capable of understanding physics. This is not alone due to greater preparation, which he may have had in other branches, but also to greater strength of will in maintaining an attitude of inquiry and discovery towards facts. Physics in the senior year in the high school course is in its right place. As much may be claimed for other branches, of course, but it is probable that in no branch is there as much real advantage as in physics.

Regarding previous preparation, nature study in the grades is a very positive factor in determining the high school course in physics. So much so, in fact, that we feel warranted in saying that

if we are to broaden our courses in physics commensurate with the progress of science and of education, much of the very elementary qualitative work which has heretofore been included in the high school course must be taught in the grades. If such facts as the existence of an atmosphere around the earth, the weight and composition of air, motion of air producing wind, existence of water vapor in air, condensation of vapor to produce clouds, rain and snow, are to be taught in physics, then we shall have scant time for such subjects as barometers, atmospheric pressure, density of air, humidity and the general properties of gases and the explanation and illustration of the laws of Boyle, Charles and Dalton. Likewise, the existence of gravity and the attraction of bodies to the earth, the existence of static electricity and various ways in which it may be made visible, buoyancy of liquids and other common properties of matter are facts which should be known to the beginner in physics. It would seem, in fact, that to claim any progress in science in the schools, such elementary facts must be acquired previous to the high school course in physics. It is not necessary to accomplish this to advocate a course in physics in the grades. The usual correlation with language and geography suffices, but it is desirable that certain known amounts of the work be done.

A further preparation for physics is the requirement that students take a course in physical geography before taking physics. This may seem like overdoing preparation for a branch which should meet the conditions, as many other branches do, without regard to previous preparation. But there is no good reason why physical geography may not serve as a preparation for physics just as physiology does for biology, algebra for geometry, composition for rhetoric and literature.

In mathematics, a year and a half of algebra and half a year of geometry, or two years of algebra and geometry along with physics, should be the minimum. Problem work in composition and resolution of forces and velocities, motion on the inclined plane, gravity and gravitation, the pendulum, circular motion, electrical resistance, and the determination of force, work, energy and power can not be carried on to advantage without it.

But there is another and even more important phase of prep-

aration pertaining to the power of the mind of the student to see relations between percepts and elementary concepts. Our sense organs, the eyes, ears, nose, mouth and skin, are, in a sense, "look-outs," constantly being impressed with things around us which is not part of us and beckoning the mind to notice. These effects of external things on our senses are what we know as sense impressions; when the mind takes notice of a sense impression, an image of the thing called attention to is formed in the mind, and this constitutes what we know as a percept: Percepts correspond, therefore, to things around us—cats, dogs, horses, wagons, cars, engines, houses, and other things innumerable. Now, it may be that some of these percepts have certain common characteristics, in which case they may be placed together in a group, and then we have what we know as a concept. This grouping may continue and groups may be placed together in classes, and classes in orders, and so on to the limit of conception. In each case a concept more complex than the previous is formed. Concepts, therefore, differ widely in content, by which we mean usually the number of included percepts or more elementary concepts. Some concepts have enormous content, as, for instnce, animal and plant. These two concepts include, in fact, every living thing on the face of the earth. Every common noun in the dictionary and out of it is a concept. Every definition is the summary of relations in a complex concept. Concepts are not the product of one mind alone, but they are handed down from generation to generation, and are constantly undergoing change, which is usually an increase in content. Cuvier left the concept fish very large, but Agassiz left it larger, and Goode left it still larger.

The acquisition of these concepts is the problem of the modern student, and not that alone, but the elementary concepts must be acquired in as short a time as possible. It is the work of the teacher to aid the student by calling his attention to the relations between percepts and elementary concepts in order that new and more complex concepts may be formed in the student's mind. The skillful teacher selects, not any number of percepts or concepts which may be related and bear upon the subject, but type concepts, which will enable the student to see quickly the relations sought.

The student brings to the subject in hand his experiences, which are, for the most part, percepts and elementary concepts. If these are not sufficient for the work, he is not likely to meet with success. He does not see relations, for the reason that there is not in his mind the necessary percepts and concepts to establish relations. He needs more training in the acquisition of sense percepts. It may be nature study, it may be arithmetic, or some other foundation study. The teacher, who has the student in charge, will do well to teach the student these elementary facts, but this can be done only to a very few. If the student's work is planned rightly, however, his preparation in one study will fit him for the next. The belief in the idea that a student needs all the preparation he can get for a difficult subject is well founded. It is founded upon sound psychological principles. The idea that a student can cope as successfully with a difficult subject during the first year in the high school as during the third or fourth must be founded on either a wrong notion of the subject or a wrong notion of how knowledge is acquired. Moreover, the indiscriminate mixing of Freshmen, Sophomores, Juniors and Seniors in classes, taking the same subject, as is done in some schools, may be justified in a way, but there is certainly no valid psychological or pedagogical basis for it.

The time devoted to physics is now almost without exception a year, which is sufficient, providing the most elementary facts of physics are known as a preparation for the course.

The matter of equipment ought not to effect the scope of a course in physics, except in relation to laboratory work. If there is little or no quantitative laboratory work, much of the problem work in physics will be burdensome and uninteresting, as, for example, the reduction of gas volumes, density and calorimetry, and it would be well to eliminate it. Laboratory work, which is mostly qualitative, is seldom as valuable as it is supposed to be and is sometimes detrimental. Students waste time doing things without having any definite accomplishment in view or obtaining any definite result which will react and stimulate to harder and better work. Qualitative experiments are performed to the best advantage and with the best results by the instructor before the class.

But in the absence of equipment it might be necessary to curtail even these.

Utility as a basis for the determination of what shall constitute the subject matter of a course of study in physics deserves careful attention. Subjects relating to matters of utility are usually closely related to the student's experience and are exhaustless sources for concrete illustrations and practical applications of principles. Moreover, utility wields a strong influence for reasons of business. On the utility basis, much of what is included under static electricity might well be omitted; so also a portion of magnetism, calorimetry, light relating to optics, sound relating to music, and a number of other subjects equally destitute of the practical. On the other hand, secondary batteries, the dynamo, the motor, the transformer, the incandescent lamp, the arc light, the telephone and telegraph should receive the fullest treatment.

Furthermore, considerations of interest deserve recognition. Subjects which are currently much heard of and read of awaken a curiosity and interest which is indispensable to good work in physics. This is particularly true of subjects like wireless telegraphy, the X-rays, the phonograph and liquefaction of gases. A course in physics could not be considered sufficiently complete without including one or more of these subjects.

These, then, are guiding principles in the selection of a course of study:

1. Requirements corresponding to the age, mental attainments and previous preparation of the student.
2. Requirements corresponding to equipment and facilities for work.
3. Requirements of utility, and
4. Interest requirements.

How much under each of these is to be taught in an elementary high school course is largely determined by the requirements of the first, and particularly previous preparation.

THE STUDY OF ANIMAL BEHAVIOR.

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In our study of the ways in which animals react to particular stimuli or to such complexes of stimuli as may be called "situations," it is always of interest to note whether there is any profiting by experience whether the animal is able to learn, and if so, precisely how and with what degree of rapidity. The mere fact that a crab, or turtle, or frog is able to learn to avoid a dangerous object is important, for it indicates the existence of complex neural processes which are probably lacking in some organisms; but of still greater importance for our understanding of the life of an organism is a knowledge of the manner of learning and of the degree of permanency of the structural changes which condition memory. Now, we may ask, Is a crab able to learn that one portion of an aquarium contains food? Does it see the food; does it smell or taste it, or has it merely formed a habit of moving in a certain definite path?

Our study of animal behavior is primarily directed toward an analysis of the various modes of activity which are exhibited, and the determination of the factors, external and internal, which modify or call forth action. As soon as we attempt to account for acts in psychic terms, or for mental processes as such in terms of brain processes, our work is futile. Whether or not consciousness is an epiphenomenon, something which may accompany a bodily change but in no way conditions behavior, it is not necessary for the biologist to decide. His proper task is to discover how the organism under observation lives and develops; everything necessary for his descriptions he finds in the terms of his own science. Let us then call the kind of work we are about to discuss biological, as it properly should be called, not psychological.

If we set out with the question, "Is this particular species of animal able to profit by experience?" we shall find many methods available for our use. Some of them are unsuitable because of inconveniences, others because they involve the inhibition of important instincts, and still others because they do not involve any activity which is natural to the organism. There are certain con-

ditions, then, which should be fulfilled by our method of testing the ability to learn: First, the reactions involved should be such as the animal naturally performs, such, for example, as escape from enemies, obtaining of food, seeking of members of its species; second, it should furnish an opportunity for records which will indicate the rapidity of learning as well as the degree of permanency, and, finally, it should be economical of time and controllable by the experimenter. In taking up experimental studies in animal behavior it is necessary to choose healthy, active specimens if time and patience are not to be used to little purpose.

Results which I have obtained[1] by the use of a simple labyrinth method, in which the obtaining of food was the motive for the reaction, are based on the following experiments fulfilling the above conditions. A large aquarium was separated into two portions by a wire screen partition. In the middle of the screen there was an opening large enough to permit the crabs to pass from one end of the aquarium to the other. Meat was placed in the end of the aquarium away from the crab. The experimenter then noted how long it took the animal to find the food. One trial a day was given each of the two animals used. The following records show a rapid shortening of the time necessary for finding the food, thus indicating that the crabs learned.

Number 1.		Number 2.	
Trial.	Time in Minutes.	Trial.	Time in Minutes.
1	7	1	23
2	4	2	10
3	3½	3	4½
4	4	4	3
5	2	5	2¼
6	1	6	6½
7	1	7	7
8	1½	8	1¼
9	1	9	1⅓
10	1¼	10	½

Moreover, the animals took a more and more direct course to the food with each repetition of the experiment.

Thus by a very simple and easily applied method it is possible to prove that the green crab is able to profit by experience.

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[1] Yerkes, Robert: Habit-Formation in the Green Crab, *Carcinus Granulatus*. Biological Bulletin, Vol. III, 1902, pp. 241-244. Abstracted in School Science, Vol. II, 1903, p. 31.

In some experiments made to determine whether the crawfish is able to learn, a form of labyrinth method was used.[1] A wooden box (Fig. 1) 35 cm. long, 24 cm. wide and 15 cm. deep, with one end open and at the opposite end a triangular compartment which communicated with the main portion of the box by an opening 5 cm. wide, served as an experimenting box.

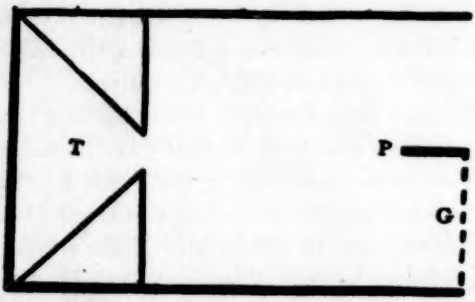

Fig. 1. Ground Plan of Labyrinth. *T*, triangular compartment from which animal was started; *P*, partition at exit; *G*, glass plate closing one exit passage. Scale ⅛.

At the open end of this box a partition *P* 6 cm. long divided the opening into two passages of equal width. Either of these passages could be closed with a glass plate *G*, and the subject thus forced to escape from the box by the choice of a certain passage. This box, during the experiments, was placed in the aquarium in which the animals lived. In order to facilitate the movement of the crawfish toward the water, the open end was placed on a level with the water in the aquarium, and the other end was raised so that the box made an angle of 6° with the horizontal.

Experiments were made under uniform conditions, as follows: A subject was taken from the aquarium and placed in a dry jar for about five minutes, in order to increase the desire to return to the water; it was then put into the triangular space of the experiment box and allowed to find its way to the aquarium. Only one choice of direction was necessary in this, namely, at the opening where one of the passages was closed. That the animal should not be dis-

[1] Yerkes, R. M. and G. E. Huggins; Habit-Formation in the Crawfish, *Cambarus Affinis*. Harvard Psychological Studies, Vol. 1, 1903, pp. 565-577. (Psychological Review Monograph).

turbed during the experiment the observer stood motionless immediately behind the box.

Before the glass plate was introduced a preliminary series of tests was made to see whether the animals had any tendency to go to one side on account of inequality of illumination, of the action of gravity, or any other stimulus which might not be apparent to the experimenter. Three subjects were used, with the results tabulated.

	Exit by Right Passage.	Exit by Left Passage.
No. 1	6	4
No. 2	7	3
No. 3	3	7
	16	14

Since there were more cases of exit by the right-hand passage, it was closed with the glass plate, and a series of experiments made to determine whether the crawfish would learn to avoid the blocked passage and escape to the aquarium by the most direct path. Between March 13 and April 14 each of the three animals was given sixty trials, an average of two a day. In Table I the results of these trials are arranged in groups of ten, according to the choice of passages at the exit. Whenever an animal moved beyond the level of the partition *P* on the side of the closed passage the trial was counted in favor of the closed passage, even though the animal turned back before touching the glass plate and escaped by the open passage.

HABIT FORMATION IN THE CRAWFISH.[1]

Experiments.	No. 1. Open.	No. 1. Closed.	No. 2. Open.	No. 2. Closed.	No. 3. Open.	No. 3. Closed.	Totals. Open	Totals. Closed.	Per cent. Open.
1-10	8	2	5	5	2	8	15	15	50.0
11-20	4	6	8	2	6	4	18	12	60.0
21-30	6	3[2]	8	2	8	2	22	7	75.8
31-40	9	1	8	2	8	2	25	5	83.3
41-50	8	2	8	2	7	3	23	7	76.6
51-60	10	0	8	2	9	1	27	3	90.0
TEST OF PERMANENCY OF HABIT AFTER FOURTEEN DAYS' REST.									
61-70 (1-10)	6	4	8	2	8	2	22	8	73.3
71-80 (11-20)	6	4	8	2	7	3	21	9	70.0

[1] The experiments of this table were made by F. D. Bosworth.

[2] One trial in which the subject failed to return to the water within thirty minutes.

In these experiments there is a gradual increase in the number of correct choices (*i. e.*, choice of the "open" passage) from 50 per cent for the first ten trials to 90 per cent for the last ten (trials 51-60). The test of permanency, made after two weeks, shows that the habit persisted.

Although the observations just recorded indicate the ability of the crawfish to learn a simple habit, it seems desirable to test the matter more carefully under somewhat different conditions. For in the experiments described the animals were allowed to go through the box day after day without any change in the floor over which they passed, and as it was noted that they frequently applied their antennæ to the bottom of the box as they moved along, it is possible that they were merely following a path marked by an odor or by moistness due to the previous trips. To discover whether this was really the case experiments were made (which we shall not stop to describe in detail) in which the box was thoroughly washed out after each trial. These experiments proved that the labyrinth habit is not merely the following of a path by the senses of smell, taste, or touch, but that other sensory data, in the absence of those mentioned, direct the animals. So far as these experiments indicate the facts, there are at least four sensory factors of importance in the formation of a simple labyrinth habit: the chemical sense (smell or taste), touch, vision, and the muscular sense.

For the study of the associated processes, sensory discrimination and permanency of impressions in frogs, I have again employed labyrinth methods.[1]

Casual observation seems to indicate that the frog is little more than a reflex mechanism, an automaton, provided with a stock of reactions which it is able to use almost perfectly, but to which it has slight ability to add anything. The stereotyped appearance of the frog's activities is just as evident of our studies, carefully, the ability of the animal to profit by experience, yet by patient observation one finally notes the slight modification of acts to meet new conditions. Frogs profit by experience slowly as compared with most

[1] Yerkes, Robert Mearus: The Instincts, Habits, and Reactions of the Frog. Part I. The Associating Processes of the Green Frog. Howard Psychological Studies. Vol. I, 1903, pp. 579-597 (Psychological Review Monograph).

vertebrates. They have surprisingly strong tendencies to repeat any act once performed, and this is true whether the act be of use to the animal or not. Doubtless, we may explain habit formation as in part the result of this tendency. A frog which has once jumped up at a certain place in a box in which it is confined, whether it succeeded in escaping by doing so or not, is very likely to do the same thing the next time it is placed in the box.

As an illustration of the way in which simple associations may be formed or inhibited, let me quote from one of my papers: "A small box with an opening of 15 cm. by 10 cm. was arranged so that the animal could escape from confinement through the upper part of the opening, the lower portion being closed by a plate of glass, 10 cm. by 10 cm., leaving a space 10 cm. by 5 cm. at the top. One subject placed in this box escaped in five minutes, forty-two seconds. After five minutes' rest, it was given another trial, and this time got out in two minutes, forty seconds. The times for a few subsequent trials were: third, one minute, twenty-two seconds; fourth, four minutes, thirty-five seconds; fifth, two minutes, thirty-eight seconds; sixth, three minutes, sixteen seconds. Although this seems to indicate some improvement, later experiments served to prove that the frogs did not readily form any associations which helped them to escape. They tended to jump toward the opening because it was light, but they failed to learn, with twenty or thirty experiences, that there was a glass at the bottom to be avoided. Thinking that there might be insufficient motive for escape to effect the formation of an association, I tried stimulating the subject with a stick as soon as it was placed in the box. This frightened it and caused violent struggles to escape, but instead of shortening, it greatly lengthened the time required for escape. Here was a case in which the formation of an association between the appearance of the upper part of the clear space and the satisfaction of escape from danger would have been of value to the frog, yet there was no evidence of adaptation to the new conditions within a reasonably short time. There can be no doubt that continuation of the training would have served to establish the habit. This very clearly shows the slowness of adaptation in the frog, in contrast with the

rapidity of habit formation in the cat or chick; and at the same time it lends additional weight to the statement that instinctive actions are all important in the frog's life. A few things it is able to do with extreme accuracy and rapidity, but to this list new reactions are not readily added. When put within the box described, an animal, after having once escaped, would sometimes make for the opening as if it knew perfectly the meaning of the whole situation, and yet in the very next experiment it would wander about for half an hour, vainly struggling to escape."

Thus far we have confined our attention to experiments which involved only a few simple associations. We may now turn to more complex labyrinth methods. A labyrinth may involve only one choice of direction or hundreds; it may have no blind alleys or many; it may involve the following of a long and devious path with many turnings upon itself, or only a straightforward movement, with the avoidance of certain obstructions; it may contain associational factors which come through any of the senses.

One labyrinth which I used for frogs consisted of a wooden box, 72 cm. long, 28 cm. wide and 28 cm. deep, with a small box at one end, which served as an entrance passage. Within this box partitions were so placed as to form two blind alleys. At two points a choice of direction was necessary: at the entrance and at the exit. At the entrance colors were introduced for the purpose of testing the frog's ability to distinguish them. The side blocked by the partitions, *i. e.*, the side which the frog had to avoid in order to escape from the labyrinth to the tank of water at the exit, was covered with red cardboard; the opposite side with white cardboard.

In the following results the experiments were made in series, often with ten-minute intervals between trials, one series per day being taken. The column marked "right" contains the cases in which the animal chose the open passage; the "wrong" column contains the cases in which the animal made a mistake and had to retrace its course in order to escape:

Trials.	Entrance. Right.	Wrong.	Exit. Right.	Wrong.
1-10	1	9	4	6
11-20	2	8	5	5
21-30	4	6	7	3
31-40	5	5	6	4
41-50	5	5	8	2
	(17)	(33)	(30)	(20)
51-60	9	1	8	2
61-70	6	4	10	0
71-80	7	3	9	1
81-90	9	1	8	2
91-100	9	1	7	3
101-110	10	0	10	0
	67	43	82	28

In this experiment the number of errors, decreasing from the first series, indicates the formation of a habit.

There are three quantitative expressions of labyrinth habit formations: the time required for a reaction, the number of errors, and the length and approach to directness of the path followed. In the experiments with crabs the "time of reaction" was used as a measure of the rapidity of habit-formation. Here we use the number of errors and the nature of the path followed. As it is not easy to give a mathematical description of the path followed, we usually indicate it by keeping graphic records of each trip. Comparison of such records shows that whereas at first the path followed by an animal is exceedingly obvious, it becomes direct after a number of experiences. A consideration of the elements of which the labyrinth habit is made in the frog indicates that the most important sensory factors are the visual impressions of form, color and brightness, and the tactual-muscular impressions resulting from the direction of turning.

The significance of the direction of turning appears when, all other conditions remaining constant, the blind alley is shifted from one side of the box to the other, thus necessitating turning in just the opposite direction. In such a case the animal usually persists in turning as it has learned to, and it is difficult to break up the habit.

It is of interest to notice the nature and meaning of a simple association as exemplified by the following tactual-electrical asso-

ciation. On the bottom of the labyrinth a series of electric wires were so arranged that by the closing of a key the frog could be given a weak shock each time it made the mistake of entering the blind alley. Since the experimenter did not close the key until he saw the frog in the blind alley, the animal each time received the tactual impression of contact with the wires before it felt the electric shock, consequently there was the possibility of the tactual impression becoming the sign of a coming painful electric impression, and calling out the reaction appropriate to the latter. As a matter of fact, I noticed that, after many experiences, the instant the frog touched the wires, and before it had received the shock, it would suddenly wheel around and jump away, thus showing that an association of the tactual impression with the electrical had occurred, so that the frog did not react to the peculiar tactual stimulus as it did at first, but in a manner suitable for the electrical stimulus.

An experimental study[1] of the association processes of the turtle has shown that reptiles are able to learn simple labyrinth paths. They profit by experience more quickly than frogs. One must always take into account the habits of the animal to be studied as well as its instincts before commencing on experimental investigation, for the latter should determine the method of study and the former should greatly aid in the interpretation of results. Turtles are very easy to keep in any school room, for they require little space, usually eat well and are readily tamed. Striking individual differences are noticeable in the rapidity of learning and in the permanency of habits. It is, therefore, of interest to study several individuals and compare their behavior.

Dr. Albrecht Bethe[2], in testing the learning ability of the green crab, *Carcinus maenas,* made use of the following methods: A crab was put into an aquarium, in the darkest corner of which an *Eledone* (an octopod) rested. The crab instinctively scurried off into the dark region, was seized by the Eledone and drawn under

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[1] Yerkes: Robert Mearus: The Formation of Habits in the Turtle. Popular Science Monthly, 1901, Vol. 58, pp. 519-525.

[2] Bethe, Albrecht: Das Centralnerven-system von *Carcinus maenas.* II Theil, Arch. f. Microscop. Anat., Bd. 51, 1898. S. 447.

its mantle. The experimenter now freed the crab from its enemy and returned it to the other end of the aquarium. Again the crab returned to the shadow, was seized, freed, and returned to the light region. This was repeated several times without any sign that the crab could learn to avoid its enemy. In another test, crabs, in a basin, were baited with meat, and each time they attempted to get the food they were seized and maltreated by the experimenter. Thus an attempt was made to teach them that meat, under certain conditions, meant danger. But in this test also several repetitions of the experiment failed to teach the crabs to avoid the danger.

What should be noted is that Bethe's tests are unsatisfactory, because in each he is working against a strong instinct. In the first test the crab naturally sought to escape from the experimenter and hide in the dark corner; in the second, the food seeking reaction, one of the most important modes of behavior, stood in the way of the formation of the new reaction which the experimenter sought.

Bethe obtained no evidence of profiting by experience, simply because he did not repeat his experiments often enough to overcome the instinctive reactions above noted.

Enough has been said to make clear the wide applicability of the labyrinth method in the study of animal behavior. Of the many types of method which are drawn, I have discussed only this one, because it has already furnished us with some excellent results as illustrations, and because it is easy to use. Those who undertake some simple experimental work on habit formation will find the study interesting in itself and valuable for the familiarity with the animals studied, to which it will inevitably lead.

It will be a pleasure if I can in any way assist any one who wishes to undertake a study in animal behavior.

PHYSIOGRAPHY IN THE LABORATORY.

BY S. BELLE HILANDS,
Madison, Ind.

It has been a question in my mind for some time as to why physiography occupies so small a place in the discussions of our science meetings. The question was answered a short time ago by the statement of one of the science men of our state that physiography has no legitimate place in the high school course; that it is a science adapted to those schools which are poor in laboratory equipment for botany and zoölogy, physics and chemistry in cities small enough to permit of out door study.

No one will deny that out of doors is the place to study physiography and that field work is as necessary to effective work along that line as it is to plant or animal ecology—as necessary, but not more so. That a subject so rich in information, stimulating to scientific investigation, broadening to one's knowledge of things met with in every day life, should be left out of the course of study because of the impracticability of field work seems, at best, unfortunate.

Botany and zoölogy both treat of life. Life principles are essentially the same in both. Plants and animals alike require air, water, food, heat and light to perform their life functions. Both grow and multiply; meet conditions favorable and unfavorable to their existence. Decrease of water, change of temperature, character of soil, topographic forms, influence animals and plants equally. Both meet unfavorable conditions in much the same ways—they adapt themselves to changed conditions, migrate, or die. Both meet essentially the same hindrances to migration, both use the same agencies.

Teach a pupil the foundation principles of one subject and he can, for himself, work out the other, while a bigger subject, one which is of wider interest, one which is met with in every phase of plant and animal life and one which the pupil must meet with again and again, remains a dark continent to him.

It is not my purpose to discuss the place which physiography does or should occupy in our schools. It is a subject which, I

believe, will make a place for itself in all our largest schools. Neither is it my purpose to outline a course of study. Each teacher of physiography who is also a student, is his own best judge of that, for the course in this as in ecology must be fitted to the place.

It is rather my purpose to make a plea for the better recognition of the science in our meetings, that teachers of physiography may gain strength and inspiration from contact and mingling of ideas, as do the teachers of other sciences. And that I may justify the presence of my subject on the program to show something of what can be done with the science of physiography, in schools where field work, for various reasons, is impracticable—what can be done with physiography in the laboratory.

The equipment may vary between as wide limits as that of a botanical or chemical laboratory. Tables where maps can be laid for study, where clay can be molded, where rocks, soils and minerals can be examined are the first requisites. Shelves for the keeping of specimens, cases for the preservation of maps from dust, a good globe and a choice collection of the best models; a large number of topographic maps—the typical and instructive sheets from all the states; the three-sheet map of the United States issued by the United States Geological Survey; a liberal collection of the common minerals and rocks from different regions of the United States; varieties of limestone, shale and sandstone, glacial boulders and conglomerates from our own state; coarse and fine grained granite and the minerals which compose it; rocks that show intrusions of different minerals; a collection of rocks from the source to the mouth of a stream showing wear on the surface; specimens that show stages in the development of sedimentary rocks; soils. The collection can not be too liberal. Photographs —best substitute for the object of study (a large collection from a variety of sources is easily obtained; the annual reports from the U. S. Geological Survey furnish excellent ones)—pictures from circulars and guide books issued by railway and steamship lines, and from the various periodicals; and last, a library chosen with special reference to the place which the subject occupies in the course, but including, always, the best elementary text books

on physical geography and geology. In its literature, at least, physiography may take first place among the high school sciences—in literature adapted to every stage of the pupil's advancement. And since physiography is always in the making, a scrap book, or, better, a folio where clippings properly mounted for use can be collected and kept, is a useful addition to the library. So much for the equipment of the laboratory. Its lasting quality is in itself a high recommendation. The pupil's own equipment consists of: a laboratory note book with drawing pad, pen, pencil, colored pencils and rule. He will need a hand lens during his study of rocks, rock-weathering and soils.

Physiography is a big subject if we include the sun, moon and stars and all the planets of the solar system, but we need not reach out to Neptune to understand the simple principles of earth sculpture, the land forms as we see them, their origin and structure. No wider knowledge of physics and chemistry is needed as a basis for this than botany, and I shall endeavor to prove this by developing, in the laboratory, two subjects in physiography commonly dealt with in the field. And, in the laboratory exercises, I treat the subject as an elementary science, adapted to the first or second year.

That part of the earth with which all life comes most in conscious contact, perhaps, is the soil, the outer covering of the solid earth. What is it? Whence comes it? We have specimens in the laboratory. Unlike those of animals and plants, it costs nothing to preserve them. Specimens of sand, of clay, of humus from the forest, of muck and marl from the lakes; of glacial and alluvial deposits. Here is basis for comparison and contrast for study of structure and origin. Different stages of plant disintegration answer the question of the humus; the microscope reveals the nature of the sand and clay, while it shows the presence of a variety of elements in the glacial and alluvial soils.

The study of soils leads to the study of the materials which compose them. The study of sand leads to sandstone, of clay, to shale and impure limestone, while the materials found in certain glacial soils necessitate the study of granite. Again, comparison and contrast; tests for hardness, for porosity, for solubility in dilute acid.

It is found that dilute acid dissolves the cement which holds the sand grains together, leaving the separate grains to crumble. The pupil discovers that rubbing two pieces of sandstone together or a piece of sand and limestone causes crumbling of the softer rock. Movement of one rock over another brings about the same result. He finds, also, that a piece of limestone can be reduced to soil by simply breaking it into smaller and smaller pieces—crushing it in a mortar. The experiments are simple, but they have their value in being devised by pupils who were set to work out the problem of the soil. Now apply these experiments. The pupil has found that at least three processes may be concerned with the production of soil from rocks; solution and the consequent crumbling of the undissolved material, breaking or crushing, and grinding. What are nature's agencies? A series of experiments testing the solvent power of water on various minerals; experiments to prove that water penetrates rocks; that water, which drains through certain loose and coarse-grained rocks, carries material with it; prove that water is the great solvent. Experiment proves that a few drops of acid hastens the solvent action on some rocks. We know that animal and plant life exhale carbonic acid gas. It takes but a simple experiment to prove that this gas is soluble in water. Again apply. Moisture in the air dissolves the gas and nature therefore uses the weak carbonic acid to aid the water in disintegrating rocks. What are the agents for breaking and grinding? Fill a stone vessel with water and allow the water to freeze. The vessel breaks. Saturate a piece of shaly limestone with water and expose it to freezing temperature for a succession of nights. The rock will split into thin laminæ. Heat a thin piece of rock and cool it quickly. Again, it breaks. And we have partially answered the question.

The pupil would get a mistaken idea of the time element were he to get his impressions from these experiments alone, just as he would if all his knowledge of a forest were derived from his laboratory work on stems and leaves. He is now ready for the library and the text on soils, rocks, and rock-weathering; for examination of specimens of rocks showing fresh surfaces and surfaces that have been exposed for a long time. A specimen which will show quickly

the different effects of dry and moist atmosphere is limestone in which nodules of iron pyrites are embedded.

But weathering does not include the other process of making soil—the grinding of rock surfaces together. There must be something which will move the rocks, and that something must itself be moving. Water, allowed to drop on coarse-grained sandstone, whose particles have been loosened by dissolving the cement, causes movement of the particles and a rubbing of the grains against each other. The water settles in the depressions where the most material has been dissolved, or it overflows at the lowest point, carrying the particles with it.

If the laboratory is in a well lighted basement, or if a basement is available for certain exercises, a large tank, a sprinkling can and a pile of sand will show this action on a larger scale; will show, too, what material is carried along the bottom of the stream that that is developed, and what is taken up and held in suspension by the water. The experiments prove only one thing, but that is fundamental—that water, moving water, is able to carry rock particles. Increase the force of the stream and the carrying power is increased. Examination of rocks collected from the mouth to the source of some stream with special reference to this subject proves the truth of the hypothesis that the grinding of material is accomplished by the materials themselves and that one of the agencies in moving the loosened materials is water.

And by this simple experiment we are introduced to a large subject, the subject of erosion.

With the sprinkling can, the tank and various kinds of earth can be worked out in miniature all the principles of rain and stream erosion.

The tendency of the water to run off from all sides equally when the material is alike and the slope the same, the unequal cutting when materials are different; the movement of particles; the beginning of a valley; the gradual widening of a tiny gorge; the transportation of materials to lower levels; the caving in of banks—all these features can be seen by a careful manipulation of the sprinkling can and adjustment of the pile of earth. Introduce a layer of well packed clay and a new feature will be added; or

stones of varying size and miniature rapids will be formed when the stone is encountered by the down cutting. The working back of the valley, the development of tributaries, the dissection of the surfaces, all are typical of what nature is doing on a large scale outside. Let the water in the tank be lowered and the water from the can applied as before. Now it gathers in the channels made for it and runs off, carrying materials with it, which are deposited in the shallow water. The formation of deltas, the distribution of deposited materials, and the character of the surface can be studied. Let the water be lowered still more, and the deposited material becomes land surface; compare the old with the new—the rough dissected topography with the smooth surface of that which was deposited under water.

And all this time the note book must be the pupil's and the teacher's best friend. When work with the sand pile begins, drawing must, also. Surface and profile views of the small valleys developed at different stages of erosion must accompany the notes.

Now, time is well spent in the study of a few good models—relief maps, showing valleys in different stages of development; of photographs, of young valleys, valleys in early and late maturity, valleys in old age—all the characteristic features noted. A study of topographic maps, tracing the skeleton outline of any stream with its tributaries, showing the prevailing angle at which the tributaries enter the main stream; of a number of maps for exceptions to this angle, or trellised drainage; profile and cross-section drawings of valleys at various points from mouth to source.

But time does not permit of further detail. From the pile of earth in the basement, from models, photographs and maps, waterfalls, flood plains and meanders, deltas and distributaries, water gaps, lake-filling, mature and imperfect dissection by streams, hindrances to valley development, can be shown, definitely and clearly, in the laboratory by proper directions, outlines and questions from the teacher.

Again, we are ready for the library and the text, and the great river systems of the United States and of the world are open to the pupil's voyage of discovery.

I have endeavored to indicate by this, perhaps, too detailed

and elementary development of the subjects, weathering and erosion, the possibilities in physiography as a laboratory science. I would say, however, that no science has less need for a laboratory, for no science in the high school course has such easy access to abundant material in the field, everywhere. Even in a large city, stones in buildings are weathering, monuments are crumbling, rain is washing soil from streets where rock has been beaten to dust by horses' hoofs; water is running along the gutters carrying material with it; gulleys are formed where fresh earth is exposed; excavations reveal the character of the soil or rock beneath the surface. So that, while field work with the class may not be practicable, the class can always do field work, and physiography in the laboratory is for the pupil. Physiography in nature's laboratory—the great "out doors."

THE GERMAN POTASH INDUSTRY.*

Prior to the nineteenth century the potassium salts were of greater commercial importance than those of sodium. While this order has been reversed since the invention of the LeBlanc process, yet the demand for potassium salts, chiefly for agricultural purposes, steadily increased until it became greater than the supply. This demand has been met by the discovery of the German deposits.

The region in which these deposits occur is a narrow one, lying between Halle and Magdeburg, Hildesheim and Bitterfeld. Between Magdeburg and Halle a large group of shafts has been sunk, and the center of the group is Stassfurt. In the thirteenth century salt springs and wells were known all through this region, and from them a certain amount of salt was obtained. In the seventeenth century these became the property of the Duchy of Anhalt and in 1796 came into the possession of the Prussian gov-

* Abstract of an address by Prof. Chas. R. Sanger, of Harvard University, made before the New England Association of Chemistry Teachers.

ernment. When rock salt was discovered in other parts of Germany the wells and springs were given up here, as elsewhere, and shafts were sunk at different places for rock salt. In 1839 the first boring was made in this district; in 1843 the shaft met rock salt at 256 meters. Later a depth of 581 meters was reached without apparent change, while the brine, contrary to expectation or desire, contained much potassium and magnesium. In the hope of finding other deposits which would give a better quality of salt, the construction of two other shafts was begun near the Bode river in 1853, and these, called "Manteufel" and "von der Heydt," were completed in about five years, being carried down to the rock salt layer at about 330 meters. The excavated material was thrown aside as entirely worthless, and was called "Abraumsalze."

Investigation of these discarded salts was made, however, by many German chemists, among them Rose and Rammelsberg, who saw, from the amount of the chlorides and sulphates of potassium and magnesium present, what a valuable deposit lay before Germany, and that it only required research to develop methods for working up the material. The rock salt of the deposits was destined henceforth to become of no value while the other salts were to be of primary importance.

After the success of the Prussian government, the Duchy of Anhalt in 1858 sank two more shafts southeast of Stassfurt, and these were opened in 1862. In 1861 Frank was the first to establish a factory in the neighborhood of the mines for the purpose of extracting the potassium chloride, which was followed in 1864 by that of Forster & Gruenberg at a place which is now a suburb of Stassfurt known as Leopoldshall. These and subsequent works and mines have resulted in raising Stassfurt from a town of 2,000 inhabitants in 1858 to 25,000 at the present time, and almost all are engaged in the salt industry.

There are now engaged in the work about twelve companies, and they control and manage twenty-three mines under the title of the "Verkaufssyndikat der Kaliwerke," with headquarters at Leopoldshall. The extent of the combination may be judged by the number of men connected with it. There were in 1901 125 executive home and foreign officers, and in the mines and works

900 officers and 20,000 laborers. The average daily output is 1,200 carloads of ten tons each. The syndicate is represented in this country by what is known as the German Kali Works.

The chief mineral salts found in these deposits are: Carnallite, $MgCl_2KCl.6H_2O$; Kainite, $K_2SO_4MgSO_4MgCl_2.6H_2O$; Kieserite, $MgSO_4.H_2O$; Sylvinite, KCl; Polyhalite, $2CaSO_4K_2SO_4$-$MgSO_4.2H_2O$; and Anhydrite, $CaSO_4$. The deposition of the salts has occurred through the gradual evaporation during countless years of prehistoric seas. As the deposits, however, reach the depth of 1,000 to 1,500 meters, the deposition is not to be explained by the ordinary evaporation of an enclosed body of water, such as is going on now, for instance, in the Dead Sea. The discovery of what seems to be regularly recurring rings of anhydrite in the main rock salt layer strengthens the theory that the sea was not enclosed except in the warm season, when the evaporation took place, and that there was an inflow during each cold season. Finally, as the sea became shut in by land, the complete evaporation took place and the salts were deposited in the order of their solubility upon the main layer of rock, salt and anhydrite. The whole deposit is covered by a layer of salt clay or sandstone. Through geological upheaval the inclination of the strata became modified, and, as a result of the formation of fissures in the clay covering, water gained access to the original deposits and changed them to various secondary compounds, according to the duration and conditions of the action.

The mines are deep and worked in many galleries. Great precautions have to be taken against the inflow of water, the shaft being cemented throughout its length. As a means of support, the rock salt, after separation from the valuable potassium salts, is returned to the excavated spaces. The mining is done by blasting. The large lumps of potash-bearing salt are mechanically separated as far as possible from the rock salt and crushed to pea size.

The crude carnallite contains 61 per cent pure carnallite, 25 per cent salt, 12 per cent kieserite and 2 per cent anhydrite and clay. The crushed mineral is elevated by a bucket belt to the extractor, a large boiler-iron vessel with false sieve bottom. The

crude material is covered with mother liquor from subsequent treatment and digested with steam under pressure. The carnallite dissolves, carrying with it a little salt and kieserite, leaving the rock salt in the extractor. The warm solution undergoes a preliminary settling, which deposits a mud of kieserite and potassium chloride, used as an inferior fertilizer. After settling, the solution passes down to the crystallizing vats, where it remains four to five days. These vats have a capacity of eleven cubic meters, from which is obtained about one cubic meter of crude chloride.

The crude chloride contains 64 to 69 per cent of potassic chloride, 20 to 22 per cent of sodic chloride, 7.5 to 8.5 per cent magnesic chloride, and 0.4 per cent bromide of magnesium and calcic sulphate. It is washed, partly with water, partly with previous wash-water, and yields a potassic chloride of 84 to 98 per cent, according to the number of washings.

The mother-liquor from the first crystallization is evaporated in multiple evaporators to the point at which the solution contains sufficient magnesic chloride to form artificial carnallite on cooling. The concentrated solution is run into crystallizing vats again, and the artificial carnallite thus obtained is decomposed with the spent wash-water from the first crop of chloride, yielding after similar treatment a second crop. The mother-liquor from this crop is now carried back to the extractor and used for the decomposition and extraction of a fresh lot of crude mineral. The mother-liquor from the artificial carnallite, containing much magnesic chloride and some magnesic bromide, is, if not worked up for bromine, allowed to escape.

Returning to the residue from the first decomposition, this is freed from the finely divided kieserite by washing, and usually returned to the mine. During the winter season, part of it is worked up for Glauber salt by taking advantage of the reaction between sodic chloride and magnesic sulphate in the cold.

The process for working up the kainite is due mainly to Precht. Briefly, it consists in decomposing the crude kainite with a small amount of water at 140° under pressure, whereby the relatively insoluble compound, $K_2SO_4 2MgSO_4 H_2O$, is obtained and the magnesic chloride is carried into solution. From the rock salt

residue, the Precht salt, being finely divided, is mechanically separated and then decomposed by a large quantity of water, whereby the ordinary double sulphate of potassium and magnesium crystallizes. On treatment of this with potassic chloride, the magnesic sulphate is converted to potassic sulphate.

The potash salts, whether chloride or sulphate, are generally separated from mother-liquors on large exhaust filters and dried by the Thelen apparatus.

The output of crude carnallite in 1861 was 2,293 metric tons; in 1901, 1,860,189 tons. Kainite was first mined in 1865 and the production has increased from 1,314 tons in that year to 1,432,136 tons in 1901. The total output of all crude mineral was in 1901 3,484,694 tons, and the supply seems well nigh inexhaustible. Some of it goes directly to the fields, but the greater part is converted to potash salts as described. All but a comparatively small portion of these salts is used for agricultural purposes. The output for 1901 was 211,421 tons of 80 per cent chloride and 28,196 tons 90 per cent sulphate, besides large quantities of other potash and magnesium salts.

In 1900, Germany led in the consumption of potash salts with 117,712 tons, the United States being second with 66,595 tons. In consumption per acre of arable land, Holland led during the same year with 3.13 pounds, Germany being second with 2.98 pounds.

THE COMMON ALMANAC AS AN AID IN THE STUDY OF THE SUN (I).

BY G. W. MYERS,

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The common (patent medicine) almanac, which can be had for the asking of any druggist, may be made highly serviceable in teaching high school classes in astronomy. A series of lessons on the interpretation of the data of an almanac is a better introduction to the sort of astronomy needed in the high school than is furnished by any text that has yet been written. This is particularly true if the almanac data are first illumined and vitalized by a little observational work on the celestial objects and phenomena on which the data are based. The lists of the calendar pages very well subserve the purpose of lists, which the astronomy class might compile from direct observation, but which the small allotment of time to astronomy often makes it impracticable for classes to undertake to collect. The best almanacs for school use are *Dr. Jayne's Almanac, Philadelphia; Ayer's Almanac, Lowell, Mass.; Hostetter's United States Almanac, Pittsburg, Penn.; Farmers' Almanac, by The Field Force Pump Company, Elmira, N. Y.; and The Old Farmers' Almanac, by William Ware & Co., Boston,* price 10c. The last two contain declinations of the sun for equidistant dates throughout the year. Any of them may be had in quantities by a teacher who will direct a request to these addresses. For the last an enclosure of 10c apiece will be necessary.

One of the most immediate problems to the beginner in astronomy is the study of the weekly and monthly variations of the length of the day measured from sunrise to sunset throughout the year. Another problem to which this one directly leads is the dependence of the law of this variation upon the latitude of the place. It is the purpose of this paper to show how these two problems may be profitably handled with high school classes.

The data for this article were taken from *Dr. Jayne's Almanac,* from *Ayer's Almanac,* and from an almanac published for Kingston, Jamaica. The latter may be obtained by addressing any druggist in Kingston.

The length of the day (from sunrise to sunset) may be found from the data of the almanac in either of two ways. First *by adding twelve hours to the almanac time of sunset and then subtracting the almanac time of sunrise from this sum;* or second, *by subtracting the time of sunrise from twelve hours and then adding the difference to the time of sunset.* Have pupils explain the reason for the correctness of the two methods.

The average day's length for each week is usually printed on the calendar page, but it is better to have the pupil discover this by figuring out a number of the weekly averages himself. A good exercise for the class just here is to determine the time of sunrise from observations made by some of its members. The observations consist in recording the watch time of rising of the upper edge of the sun and then of the lower edge to the nearest half minute. The time of rising, which should be compared with the almanac time with a view to finding the error of the almanac for the place, is the first of these recorded times. The time of sunrise,* astronomically considered, is the mean of the two observed times. Similar observations might be made also at sunset. From the two observed times find how long it takes the sun to rise.

The question may here arise as to the reason, or reasons, for the almanac error. It may be well to point out now that part of this error is doubtless due to the error of the watch. The watch may now be compared with a Western Union clock (in some railroad station or drug store) and its error found and allowed for. This would also be a good place to explain the meaning of Standard time and the Western Union's method of distributing time from the Naval Observatory in Washington, D. C. A good opportunity to review the subject of longitude and time from an astronomical point of view is also present. The part of the almanac error still outstanding, which is due to the difference between the latitude of the place and the latitude for which the almanac is computed, would better be postponed.

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*Almanacs often give the time of rising, or setting of the upper edge of the solar disk as the time of rising or setting of the sun. What difference will this make in the day's length?

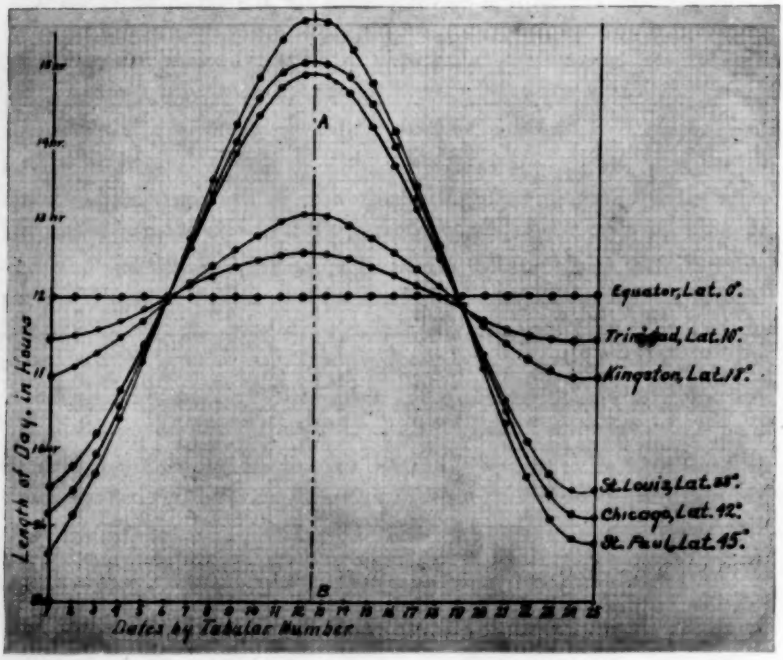
The table given below contains the data for fifteen-day intervals for the day's length as given by almanacs for 1903 for St. Paul, Chicago, St. Louis, Kingston and Trinidad. The corresponding latitudes are about 45°, 42°, 38°, 18° and 10° N. respectively. The lengths of the day should be reduced to hours and hundredths of an hour. The numbers will then be more easily plotted. This reduction will also furnish good training in the practical use of compound numbers. The day curve for the equator is represented roughly by the twelve hour line drawn horizontally across the middle of the curves for the given latitudes.

TABLE OF DAYS' LENGTHS FOR FIFTEEN-DAY INTERVALS THROUGH THE YEAR 1903 IN DECIMALS OF AN HOUR FOR INDICATED LATITUDES AND PLACES.

No.	Date.	St. Paul. Lat. 45°.	Chicago. Lat. 42°.	St. Louis. Lat. 38°.	Kingston. Lat. 18°.	Trinidad. Lat. 10°.
1.	Jan. 1...	8.62	9.18	9.50	10.93	11.43
2.	Jan. 16...	9.15	9.45	9.77	11.06	11.47
3.	Jan. 31...	9.78	9.92	10.20	11.23	11.57
4.	Feb. 15...	10.40	10.55	10.78	11.45	11.68
5.	Mar. 2...	11.15	11.23	11.38	11.68	11.84
6.	Mar. 17...	11.93	11.93	12.00	11.95	11.97
7.	Apr. 1...	12.73	12.65	12.62	12.18	12.12
8.	Apr. 16...	13.51	13.33	13.25	12.39	12.26
9.	May 2...	14.23	14.02	13.87	12.60	12.38
10.	May 17...	14.85	14.57	14.35	12.77	12.47
11.	June 1...	15.32	14.92	14.72	12.97	12.53
12.	June 16...	15.57	15.03	14.89	13.07	12.58
13.	July 1...	15.53	15.02	14.85	13.03	12.54
14.	July 16...	15.25	14.85	14.62	12.96	12.48
15.	July 31...	14.77	14.50	14.22	12.75	12.38
16.	Aug. 15...	14.15	13.95	13.70	12.56	12.25
17.	Aug. 30...	13.42	13.28	13.13	12.35	12.14
18.	Sept. 15..	12.62	12.55	12.48	12.12	11.99
19.	Sept. 30..	11.85	11.85	11.85	11.85	11.86
20.	Oct. 15...	11.07	11.17	11.22	11.60	11.69
21.	Oct. 30...	10.32	10.50	10.62	11.38	11.58
22.	Nov. 14...	9.65	9.90	10.10	11.17	11.49
23.	Nov. 29...	9.10	9.42	9.69	11.01	11.43
24.	Dec. 14...	8.82	9.12	9.48	10.93	11.41
25.	Dec. 29...	8.77	9.12	9.48	10.93	11.41

On cross-ruled paper, marked off into large squares by heavy lines, the larger squares being subdivided by fine lines into ten equal parts, and using the numbers of column one instead of the dates of column two, the values of each column from the third to the seventh are plotted as shown below. The fifteen-day inter-

vals are represented by equal spaces on the horizontal line and the corresponding days' length is plotted to tenths of an hour directly and to hundredths of an hour, by estimate, on the vertical lines. The side of a small square represents, horizontally, five days, and vertically it represents one-tenth of an hour. The plotting of hundredths of an hour by estimate is valuable training for the student in forming judgments of magnitude. The hundredths should therefore not be omitted in this plotting.



STUDY OF THE DRAWING.

Notice, first, that because of lack of room on the page the heavy horizontal line at the bottom of the page is marked eight hour at the left. On the left of the page the nine hour, ten hour, eleven hour, etc., points are indicated on the heavy vertical. The first point on the left vertical and just above the eight hour point

represents a day's length of 8.62 hour (see first number of column three of table), and is the length of the day as given by the common almanac on January 1, 1903, for St. Paul, Minn., whose latitude is about 45° north. Following along this "St. Paul-curve" from date to date, we notice that the day's length increases rapidly (shown by the rapidly rising curve), crosses the twelve-hour line about March 17 (three days previous to the vernal equinox, Why?) then continues to rise rapidly, until it reaches a day's length of 15.57 hours about half-way between points No. 12 and No. 13 (corresponding to June 23d). The curve then begins to fall very much after the fashion of its rise during the first half of the year, though reversing the steps, crossing the twelve-hour line about September 25, finally reaching its lowest point on December 29, where the day's length is again nearly what it was at the beginning of the year, *viz.*, 8.62 hours.

Similarly, let the student start with and follow through the day-line for Chicago, latitude 42° north; then with the day-line for St. Louis, latitude 38° north; then with that for Kingston, latitude 18° north; then with that for Trinidad, latitude 10° north, and finally with that for the Equator, latitude 0°, which is drawn in without data and without reference to the fact that the day is always lengthened and is also somewhat varied by reason of atmospheric refraction and of parallax. It must be remembered that we are discussing almanac data, which are not sufficiently precise to justify attempts to secure absolute accuracy.

Since the length of the day is different for different latitudes, point out here that part of the difference between observed and almanac time of sunrise is due to the fact that the almanac is computed for a latitude somewhat different from the latitude of the place of observation. In what way should almanac sunrise differ from observed? Should the former be earlier or later than the latter?

It is evident from the figure that the curves for the different northern latitudes become flatter and flatter as the latitude grows less and less and that the curve becomes a straight line for latitude 0° (at the Equator). What does this mean as regards variation of day's length with the latitude? In other words, in

the northern hemisphere, where is the difference between the longest and shortest day of the year the greatest? When does the longest day occur? The shortest day?

The date of the longest day may be found from the curve for any place by drawing a vertical line, as *AB*, through the highest point of the curve and noticing where it cuts the line of dates. In this case it cuts midway between Nos. 12 and 13, corresponding to June 16 and July 1, or the longest day is June 23 or 24.

If the almanac data were exact (and the plotting were accurate) the curves would all cross at the same point at the end of the first quarter, as also at the end of the third quarter of the year. What does this signify? At what time of the year would it occur?

It will be well to have these day-curves drawn on large charts, on paper ruled to square inches and hung upon the walls of the class room for reference. These curves will be doubly instructive when studied in connection with curves similarly constructed to visualize the law of variation in heat and light distribution for different latitudes throughout the year. This subject will be taken up by the writer in a later paper to be published in SCHOOL SCIENCE.

It will now be well for pupils to subtract the almanac times of sunrise from twelve o'clock, thus finding the length of the forenoon, and to compare this with the almanac time of sunset, which is directly the length of the afternoon. Let them find the difference between the length of the forenoon and of the afternoon for a few equidistant dates running through two or three months and compare these differences with the numbers that are given in the calendar page columns headed "Sun slow," or "Sun fast." The almanac times of rising and setting of the sun are given *in mean time*. The time interval from the rising of the upper limb of the sun to the instant when the center of the sun's disk is on the meridian (twelve o'clock apparent time) is equal to the time interval from the latter instant to the setting of the sun's upper limb. The numbers listed in the "Sun slow" and "Sun fast" columns are the differences *in mean time* between mean

noon and apparent noon (sun noon). The explanation of the coincidence of the numbers with one-half of the difference between the length of forenoon and of afternoon means an explanation of mean and apparent time. Here is the proper place for it.

The meaning of the symbols and abbreviations used in the column headed "Aspects of the Planets, etc.," should now be learned by the class. These are fully defined on the first page of the almanac and it only remains for the teacher by blackboard sketches—which must always be interpreted by actually pointing out the indicated positions on the sky—to make the definitions clear to the class. This clearing up of these definitions can be best accomplished by actually interpreting, both on the blackboard and on the sky, the actual abbreviations of the calendar pages of the almanac. In this work the pupil should be carried to the point where from the indications of the almanac he may decide just when to look for any phenomenon, or object, described in this column. It would be difficult to spend a week's recitation time of the high school astronomy class more profitably than it could be spent by a well informed teacher on the points indicated in this paper.

SOME EXPERIMENTS IN PHYSICAL GEOGRAPHY.

BY W. W. PARMENTER.

Instructor in the Oskaloosa, (Ia) High School.

In most of our high schools the subject of physical geography is taught in the first year. In the high school the pupils come in contact with new conditions and have to adopt new methods of study. To such as these, book physical geography is difficult and uninteresting. It is their first taste of science, and they are not favorably impressed. They think all their work in science will be as this has been. For these reasons I maintain that the teacher should introduce as much experimental work as possible. Of course this should be in addition to the field excursions. The physics and chemistry laboratory will furnish the necessary apparatus. I hereby give a few simple devices which I have used with success to illustrate subjects in physical geography.

GEYSER.

Take a piece of glass tubing about 75 cm. long and 5 to 8 mm. inside diameter. Bend this tube about 35 cm. from the end in the shape of an obtuse angle (Fig. 1). 10 cm. from the other end bend at a right angle. On this end connect a small funnel by a piece of rubber tubing. Draw the longer end out to a point by heating in a Bunsen or alcohol flame. Have the opening in this and one or two mm. in diameter. The top of the funnel should

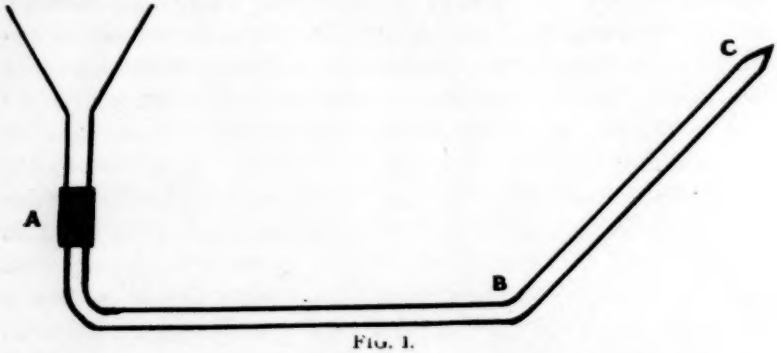


FIG. 1.

be about 5 cm. below the top of the tube. Fill the funnel with water until the water rises to the point C in the tube. Place a Bunsen burner or alcohol lamb below B so that the water will be heated. Soon the steam which is formed at B will force the column of hot water out at D with great violence. When the pressure has been relieved the water will flow from the funnel into the tube again. After a few minutes steam will again be formed and the operation will be repeated. To make the illustration more real the "geyser" can be placed under a box with only the point D extending through the bottom. Around the opening some of the rock which is formed near geysers can be placed. This arrangement gives the pupil an idea of the action of a geyser and illustrates the principle.

RAINBOW.

Nothing will delight children more than to make a cloud in the classroom and upon this cloud throw the rays of the sun and notice the rainbow. This can easily be done as follows:

Take a gas tank and pump air in it to high pressure. The tank with the Crowell outfit well answers the purpose. If you have no tank, a bicycle tire will do about as well. Connect the tank with rubber tubing to an atomizer. Turn on the air quite briskly and the water is thrown into the air in the form of a cloud. If a ray of sunlight is thrown on the cloud a very good rainbow is formed. If possible, it is best to throw the cloud into a ray of light which comes through the window. This experiment can also be used to show that the clouds are composed of small drops of water. An atomizer can easily be made with two pieces of glass tubing and a cork. The method was described in a recent issue of School Science (Vol. II., p. 358).

VOLCANO.

Take a piece of gas-pipe about 2.5 cm. in diameter and 10 to 15 cm. long. Stand it on end for a crater, and place earth around it like a miniature mountain. If you have no gas-pipe, a hollow stick or a large corncob with the pith entirely taken out will do. Prepare the following mixture: Granulated sugar, one part; ground chlorate of potassium, two parts, and a mixture of fine iron filings and powdered charcoal, one part. Mix thoroughly, and fill the crater with the mixture. Drop on the top a little sulphuric acid. At once a violent chemical action takes place. Smoke and flame are shot into the air for ten or twelve feet, depending on the size of the crater. The charcoal and iron will become red hot and shoot into the air like hot lava and rocks. The charcoal will fall for the volcanic ashes. The "eruption" will continue for a minute or two, according to the length of the crater. If the room is dark this experiment is especially beautiful. Most of the boys of the class will want the "receipt" and volcanic eruptions will be the order of the day in the town.

RELIEF MAPS.

Why pay $100 for a set of relief maps when your class can make all you will need for the sum of 50 cents? Three parts of salt and one part of flour, made into a thick paste, is an excellent and cheap preparation. Reliefs of most of the blocks and pictures

in the text can be made on stiff cardboard, and by their use various subjects can be taught to dull pupils to a much better advantage. Thus they serve a double purpose; the pupil who makes them is benefited, also the class. A few of the many things which can be made are: (*a*) Block Mountains. (*b*) Fall Line with Coastal Plain and Plateau. (*c*) Water Gap. (*d*) Oxbow Lake. (*e*) Meandering River. (*f*) Land-Tied Island, etc.

THREE PAPERS OF MORE THAN ORDINARY INTEREST. A REVIEW.

BY CAROLINE C. HARVEY,

Detroit, Mich.

"*The General Efficiency of a Technical Education,*" by Professor W. C. Mendenhall (SCIENCE, September 4), is an interesting paper discussing the value and efficiency of a technical education as a preparation for life and comparing its general influence with that of the so-called "liberal education." Since these systems have different aims, comparisons must be made on these points: the success with which each prepares a man for new and more exacting conditions and the success with which he fulfills his obligations to society and to himself. To the two educational aims—power and knowledge—Professor Mendenhall adds a third appreciation. The traditional education laid stress upon power and incidentally the third aim was accomplished. By a curious paradox, technical institutions have fallen heirs to the rigid disciplinary methods of the old school masters, so that the efficacy of technical training to accomplish the first aim of education is apparent. It is upon the broad, general side of knowledge and culture that technical training is weak. Three possibilities for improvement are suggested: to devote more time during a technical course to subjects of a general character; to lay the burden of providing this part of education to the preparatory school and by strengthening the student activities and intercourse which make up college life.

"*The New Opportunity for Secondary Schools,*" is the title of an earnest and convincing article by Professor C. M. Woodward

(SCIENCE, August 21), and is a plea for a broader and more practical education than has yet been obtained in secondary schools. One of the most conservative of British educators in a recent address says that a classical education neglects all the powers of some minds and some of the powers of all minds. The great educational problem of the day is to make the high school course of study more efficient and better adapted to the constantly increasing number of students. Gratifying results have followed the building of manual training high schools. The inquisitive and active boy knows that science may be studied and understood with no more effort than it takes to learn the grammar of a dead language. We must cut away from the tradition that culture is only secured from the study of the classics and ancient history, that the skilled hand and cultured mind are necessarily separated.

"The Summer Laboratory as an Instrument for Biological Research," is the subject of an address (SCIENCE, August 28) by Professor Judson Herrick. In substance he says: "Of the three kinds of biological stations those combining research and instruction are of the greatest value. There are two groups of conditions necessary for research, material conditions, and more vitally important, subjective conditions, that is, the culture of the investigator himself.

"History of any special investigation involves four steps: (1) the amount of the investigator's previous experience so far as it affects his mode of thought and fund of ideas; (2) the reception of an impression which directs his attention to some problem; (3) the solution of the problem involving observation and experiment; (4) the unification of the series of facts, so that facts and interpretation fit together. In proportion as the newly acquired facts and their interpretation can be broadly correlated with the existing fund of knowledge, in just so far is the research great. The summer laboratory contributes in many ways to the advancement of science. It gives stimulus and inspiration to many weary investigators by real, vital contact with other men engaged in similar work. Biological stations should be clearing houses for scientific ideas."

Metrology.*

GOVERNMENT'S ABANDONING OLD WEIGHTS AND MEASURES.

(*Concluded from page 226.*)

To fix Dec. 31, 1914, as the latest date upon which the government might legally use ancient weights and measures would be a conservative proposition. For a practical test of this proposition by what has actually been done, we have before us the experience of other countries, and especially of Norway and Sweden, which, about a quarter of a century ago, adopted the metric system in less time and under conditions similar to those of the United States in respect of racial affinity, language, political and commercial relations, development of iron manufacture, popular education, etc. To test the proposition by the judgment of men who have considered the matter, we have the fact that the published expressions of opinion generally estimate much less time as necessary.

Among the members of the Boston Society of Civil Engineers the opinion appears to have prevailed that in less than five years the use of metric weights and measures might be extended throughout the government departments; for in the latter part of 1896 a canvass was made in that society, the result of which is stated as follows by the chairman of its Committee on Weights and Measures on pages 21-2 of Proceedings published in the *Journal of the Association of Engineering Societies* for December, 1896, Vol. XVII, No. 6:

Postal cards reading as follows were sent to each member:

"I am .... in favor of the passage by the present Congress of an Act requiring the metric weights and measures to be in use by the government departments generally by the beginning of the twentieth century, January 1, 1901.

* Communications for the Department of Metrology should be sent to Rufus P. Williams, North Cambridge, Mass.

"I should .... be willing to have people generally of their own accord adopt metric weights and measures for their ordinary business transactions, and especially for those in which I am myself concerned, at the same time at which the government departments as a whole actually do adopt them."

The total number of cards sent out was	404
The total number of cards returned was	229
Number in favor of both clauses of the card	193
Number against both clauses of the card	21
Number for first clause and against second	2
Number against first clause and for second	11
Members in favor of a decimal system	2

Intelligent citizens appreciate the need of the government's completing its abandonment of old weights and measures. They must make known their will and secure by their representatives in Congress an enactment for the instruction of their public servants in the executive branch of the government something like this:

BE IT ENACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA, IN CONGRESS ASSEMBLED:

That from and after the first day of January, 1915, the weights and measures of the metric system shall be exclusively used in the business of all departments of the United States government.

With a date so far off there should be little opposition to the passage of the bill. If the whole change can be completed in advance of the limit so much the better. Officers in charge of particular bureaus have generally estimated that their work could be changed in two years or less; and in some of them it is desirable that the change be made as soon as possible so far as connections with other business will permit. In the customs service, for instance, the transition may well be completed sooner than in some other branches of service, as has generally been the case in other countries, and as has been recommended to our Congress at various times, and particularly by James G. Blaine, Secretary of State, in 1890, when he transmitted the conclusions

of the so-called Pan-American Conference, which was called by the United States expressly to consider uniform weights and measures and other subjects. Possibly in the domestic service of the Post Office department and in the Weather Bureau the change could be completed early. If in some place, like the taxation of spirits, there should be occasion for delay, it would be within the discretion of the officers in charge to have their transition process in 1913 and 1914. The essential thing is to have an assurance that all branches of government work will, within a reasonable preappointed time, exclude ancient weights and measures.

Among examples of management similar to what is above proposed it is instructive to recall the earlier experiences of this country with money, a matter closely analogous to weights and measures. A century ago it was a question of getting rid of reckoning twelve pence in the shilling, of guineas, crowns, etc., so as to use only the decimal money provided for by laws of 1785-6. The process may be illustrated by the following law of New Hampshire, approved February 20, 1794:

An Act to establish the method of computation of money in accounts and other transactions.

Whereas it is of importance to society, and will facilitate commerce, that the money of account be rendered as simple as its nature will admit; and whereas the method of notation used by the United States is easy of comprehension and will readily apply to the monies current in the commercial world, and as in case of its adoption, the actual monies and the money of account will be of the same denomination, its establishment can not be attended, on its introduction, with injury or inconvenience to the citizens of the State;

Be it enacted by the Senate and House of Representatives in General Court convened, That the legal money of account of the State of New Hampshire, from and after the first day of January, one thousand seven hundred and ninety-five, shall be in dollars and decimals of a dollar; That is to say, dollars, dimes and cents, or dollars and cents—the dollar to be of the value of the federal dollar, so-called, or dollar of the United States, and equal to six shillings of the present lawful money—the dime, of the value of one-tenth part of a dollar, and the cent of the value of one hundredth part of a dollar.

And be it further enacted, That from and after the said first day of January, the judgments of all State courts, accounts in all public State offices, and assessments in all State taxes, shall be in dollars and cents, or dollars, dimes and cents, reckoned and valued as aforesaid."

Most of the states made enactments for the same general purpose, though in various forms and at different times during the last decade of the eighteenth century. What is insisted upon is that as an actual fact the greater part of the states passed laws *fixing dates* for the exclusion of the ancient reckoning from their public accounts. It is conceivable, however, that even if people had been willing to let confusion in their state accounts continue at will the change would ultimately have been worked out.

A second example of analogous legislation was the resumption of specie payments within the distinct recollection of many men now in active business. The premium on gold having become much less than it was in the 60s, an Act of Congress was passed January 14, 1875, which said:

. . . on and after the first day of January, anno Domini eighteen hundred and seventy-nine, the Secretary of the Treasury shall redeem in coin, the United States legal tender notes then outstanding," etc., etc.

It is conceivable that the restoration of government credit might have been completed in some different way after years enough had dragged along. There was great opposition to the course adopted. The Democratic platform of 1876 contained the following words:

* * * we denounce the Resumption clause of the Act of 1875 and we here demand its repeal.

We demand a judicious system of preparation by public economies, by official retrenchments, and by wise finance, which shall enable the nation soon to assure the whole world of its perfect ability and its perfect readiness to meet any of its promises at the call of the creditor entitled to payment.

Its candidate for the presidency, Mr. Tilden, occupied half of his letter of acceptance of the nomination, dated July 31, 1876, with the subject of resumption and said:

It can not be doubted that the substitution of "a system of preparation" without the promise of a day, for the worthless promise of a day without "a system of preparation," would be the gain of the substance of resumption in exchange for its shadow.

One house of Congress voted on November 23, 1877, to repeal the Act.

The point now insisted upon is that the way in which resumption actually *was* brought about was in connection with a law fixing the date in advance. President Grant in a letter discussing resumption, which was made public in January, 1874, had written: "I would like to see a provision that at a fixed day, "say July 1, 1876, the currency issued by the United States should "be redeemed in coin," etc., etc.

The designation of the date in the future kept the prospect of change in the minds of the people and afforded time for the government's making the preparatory arrangements needed. In fact the premium on gold became gradually smaller and vanished a little before the date fixed as the limit.

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

BIOLOGY.

Thoughtful teachers will maintain that the best high school courses in zoölogy for a liberal secondary education should also satisfy the college entrance requirements. In the nature of the case such a course would embody in elementary form many of the features in a college course for undergraduates. If the student is properly instructed he will understand that these are merely beginnings of animal studies that may be continued for a life-time.

The difficulties of the college teacher seem to come when the student expects credit for advanced standing on his high school work, or when he takes a college course in zoölogy and on hearing the names of forms he has studied thinks he has exhausted the subject. He either wishes to be excused from repeating the exercise or finds very irksome what he "thinks" he has done once. Is there any study in which there will not

be some repetition, or in which the above class of students will not appear?

In discussion of a high school course in zoölogy there has been quite universal criticism of too large an amount of anatomical detail, or so much morphology as has been given in the past. This was followed by external morphology and classification exclusively going over into the old natural history style of teaching. Finally the study of the relations of animals to each other and to their surroundings (ecology) as well as the study of animal behavior (only in simple fashion, of course) are forming a large part of the best books on the subject. But progressive teachers maintain that internal structure should not be neglected to the detriment of the student's knowledge (it may be the only information of the kind he will get) of the internal organization of the animal body. Lately the suggestion has been made, from different sources, to introduce a large amount of animal physiology—much of it, perhaps, human physiology.

L. M.

From recent numbers of *"Natur und Schule"* the following interesting items are taken:

For the production of oxygen from aquatic plants two bottles may be used, offering more room for plants than the well known glass jar and funnel for this purpose. A glass tube about 8 cm. long is pushed through a cork stopper in a two liter water bottle in such a way as to allow the escape of gas from contained plants (Elodea, etc.). The upper end of this tube passes through the cork of a smaller, low flat bottle inverted over the cork of the water bottle. The bottom of the upturned squat-bottle is cracked off (with hot wire) and the upper bottle forms a pneumatic trough for collecting the oxygen in a test tube. It is stated that two to three tubes full of gas may be collected in a single class hour under favorable circumstances. Carbon dioxide should be passed into the water from time to time.

An insect case for individual study is described as follows: The insect is fastened between two watch glasses by a pin thrust into a piece of cork cemented into the under glass. A frame holds the watch glasses together. The frame consists of two square pieces of board with suitable openings, beveled on the edges toward each other to receive the edges of the watch glasses. Two screws hold the frames together.

Under "Biological Collection," it is maintained that the mania for miscellaneous collecting as well as ruthless killing of animals by students should be restricted. A good example of profitable study and collecting is given. Insect larvae found under bark, on carrion, etc., are placed with considerable of their food (on which they are found) into a wide mouth bottle or jar. One-third are preserved and labeled and the re-

mainder covered with cloth tied tightly over the mouth of the jar to keep in both the larvae and moisture. Food is renewed bi-monthly if necessary. After pupating a portion of these are preserved and labeled to correspond with the larvae already preserved. When some of the adult insects emerge they are preserved and labeled to correspond, while others are kept to get the eggs to complete the set. Thus the pupil has followed the whole life history of an insect and has kept a record of it.

L. M.

CHEMISTRY.

A Method of Testing for Carbon Dioxide.—In the November, 1902, number of SCHOOL SCIENCE, a method of testing for carbon dioxide was given. One of my students hit on a modification of that method which has proved quite satisfactory in our work. It is this: A one-hole rubber stopper is inserted in the test-tube or flask in which the carbon dioxide is to be evolved, and through the hole a small pipette (say, 10 cc.) containing a few drops of lime water is pushed, the finger being kept over the upper end until all is in place. Any gas generated forces the lime water up into the bulb of the pipette and there bubbles through. We found that a safety or funnel tube also worked well. The necessary part is the enlargement of the tube at some place in order to let the gas bubble through the lime water.

I prefer the safety tube, especially if the gas given off is small in amount, for a few drops of lime water can be introduced into the bend of the tube, but will not run down into the test-tube even if the gas pressure inside the test tube is as low as it is outside.

This makes a good lecture experiment, since the effect of the carbon-dioxide can be readily observed by the whole class.

Findlay, Ohio. JESSE H. GARNER.

Solubility of Gases.—A common lecture experiment to illustrate the solubility of hydrochloric acid and ammonia is performed by means of a flask fitted with a jet tube opening under litmus solution. There is often difficulty in starting the "fountain," particularly if the apparatus has to be made ready the day before. I have tried several schemes including that of using the medicine dropper mentioned by Benedict, but not with satisfactory success. A simple and efficient method is to expand the gas in the flask by brushing a gas flame over the upturned bottom of the flask, driving out several bubbles of the gas. On cooling the water will generally rise high enough in the jet tube to start the action. If not, a few drops of water or ether on the flask will make the matter sure.

English High School, Lynn, Mass. WM. F. RICE.

Book Reviews.

Botany All the Year Round. By E. F. ANDREWS, Washington (Ga.) High School. 21 × 14 cm. 302 pages. American Book Company. $1.00.

The author aims to bring the study of botany within the reach of the great number of students, to whom this important branch is of much practical use and yet is too often excluded from the curricula of the country and public schools, because expensive laboratory equipment is generally deemed indispensable to its pursuit. The book is written in a simple but scientific manner and rightly places emphasis upon the intimate relationship between botany and agriculture. A wise choice of material is made by the author. In most cases the plants studied are common ones, familiar to children and easily obtained in any neighborhood. Fresh material is provided for during the entire year by a somewhat unusual arrangement of the subject-matter. Many instructive experiments are described which require no appliances except those easily devised by teacher and pupil. This insures the coöperation and interest of the students themselves. The text is divided into eleven chapters, treating successively the leaf, fruit, seeds and seedlings, roots and underground stems, the stem proper, buds and blossoms, the flower, ecology, seedless plants and fungi. To each chapter are appended a number of practical questions and some excellent field notes to awaken an appreciation of common things in out-of-door life. It is a relief to find that there is not an overabundance of illustrations to distract the student's attention from the text, but those that are used are judiciously placed. The typographical arrangement is good, the subject of each division of the chapter appearing in bold faced type.

By far the longest and most complete chapter is that on the leaf. The physiological functions of the leaf are brought out in a clear, comprehensive manner and these are further emphasized by several definite, pointed experiments, fixing the phenomena of respiration, transpiration and photosynthesis firmly in the mind. "Seedless Plants" and "Fungi" form the least interesting portion of the book. This arises partly from the limited space given to these vast branches of plant life and partly from the arrangement of the groups. While sixty-two pages are devoted to the leaf alone, thirty-four suffice to cover these important fields. However, in these chapters, the perplexing subject of the alternation of generations is ably presented, and forms an interesting point around which to group certain facts. One could wish that more stress

had been laid upon that fascinating subject, ecology, especially as the book is intended as a guide for general use.

The book can be heartily recommended to the constantly increasing number of botany students desiring a general, yet accurate and scientific text-book. For smaller high schools especially those in rural districts, this manual will be of great value.

Detroit, Mich. CAROLINE C. HARVEY.

First Studies of Plant Life. By GEORGE FRANCIS ATKINSON, Ph. B., Professor Botany in Cornell University. 13.5 × 19 cm. 266 + XII pages. Ginn & Company, Boston. 1902. 60 cents.

This simple and clear presentation of methods for studying the plant at work can be successfully used by a teacher who has had little or no botanical training. In addition to the pleasing manner in which each topic is discussed, there are excellent illustrations which can not fail to clear up points not perfectly understood in the text. Professor Atkinson holds to the opinion that the thing at work rather than the thing itself attracts and holds the attention of the child. He has followed, in Part I the plant from the seed to the mature plant, digressing sufficiently to compare ways in which different parts of the same plant, and like parts of different plants, respond to the same external forces.

Part III takes up the life functions; the uses of water, starch, making, disposition of surplus water and air, and breathing, with simple experiments to demonstrate each phenomenon.

In Part II attention is given to the sensitiveness of plants, their behavior toward light, next their climbing habits; then the life history of seed plants is completed with flowers, fruits and seeds.

In Part IV is outlined the "life stories" of common plants, as the sweet pea, oak, fern and mushroom. In V a few ecological questions are touched upon. These two parts might start the wide-awake children on a little more independent study of plants in the field.

If pupils entered upon their high school course with a knowledge of plants, their life and work, such as might be gained from the use of "First Studies of Plant Life," the botanical portion of nature study in the grades could be considered a success and the high school botanical course could be made much more profitable than it is at present.

This book, because of its simplicity and scientific accuracy, should find a place in the grammar schools.

Detroit Central High School. L. LENORE CONOVER.

Mosses with Hand-Lens and Microscope. By A. J. GROUT, Ph. D. 20x28 cms. 86 pages. Published by the author, 360 Lenox Road, Flatbush, Borough of Brooklyn, New York City. $1.00.

Under the above title Dr. Grout is issuing a work on the mosses of the northeastern United States that is the *best* attempt that has ever been

made to present this rather difficult and certainly little known group of plants, in a manner comprehensible to the average student. It is a pleasure to attack an unknown moss with such a guide after wearied attempts to "run it down" with such a classic as Sullivant's, and its publication ought to be a great stimulus and help in acquiring a knowledge of these interesting plants.

The work is issued in parts (of which there are to be four or five). There is an introduction and short articles on classification, collection, preservation and working methods, and then follows a carefully written, beautifully illustrated and accurately up-to-date account of the life history of the moss. This section is especially commendable for its clearness and completeness.

There is a glossary of terms applicable to mosses illustrated with many figures, which is another excellent and desirable feature of the work. The manual of mosses follows, and it is refreshing to note, after a careful perusal of the first part of this section, that the author has adhered to the clear and as far as possible untechnical language that so commends the other sections, to the use especially of beginners.

The whole work is profusely illustrated with excellent plates and figures in the text, the paper and letter press are all that could be desired and, in short, if this review seems too one sided, it is because the writer after careful and painstaking inspection, can find nothing with which to seriously find fault.

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Reports of Meetings.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirty-sixth meeting was held in Boston on Saturday, May 16, 1903. In the morning the session was held at the Harvard Medical School, where the members listened to an address by Dr. W. T. Porter on "New Apparatus for Teaching Physiology." Before proceeding to examine the apparatus at the close of the lecture, attention was called to an ox heart, rigged up to show the working of the valves in the process of the circulation. A fresh ox heart of large size had two round windows, about one and one-half inches in diameter, tightly fastened into the top end. Rubber tubes took the place of the large arteries and veins connecting with the cavities of the heart. An electric light inside the heart lighted up the

cavities, and water was forced around by means of a large rubber bulb, enabling the observer to see precisely how the valves work. For the benefit of the members Dr. Porter showed more than fifty pieces of apparatus, varying in complexity and value from the kymograph and the circulation apparatus down to the frog board clip and the double hook from the muscle lever. Among the larger pieces were the circulation scheme, all mounted and in working order ($3.50); the capillary electrometer ($2); the artificial eye ($3); optical lantern to go with the artificial eye and adapted to a variety of other uses ($3.75); the kymograph in an improved form and very accurate, compact, light and convenient ($12); the inductorium, a form of induction coil, having the secondary coil mounted so it can be placed at any desired angle to the primary coil ($5). A pamphlet containing a full description and cuts of all the apparatus can be obtained by applying to Dr. Porter.

In the afternoon there was an address by Dr. George V. Wendell, of the Massachusetts Institute of Technology. A condensation of this address follows:

"During the last few years some remarkable and exceedingly important discoveries, bearing upon the constitution of matter and the nature of electricity, have been made by an experimental study of the phenomena accompanying the discharges of electricity through rarefied gases. For this reason one should be familiar with the fundamental facts connected with such discharges.

"When two conductors, one charged positively and the other negatively, are brought near each other, a stress is developed in the intervening medium (the insulator) and the stress may become so great as to break down the medium. The spark which passes between the conductors is usually zigzag, following the path of least resistance. The potential necessary to cause the discharge is a function of (1) distance between the conductors, (2) form and polish of the electrodes, (3) nature and previous history of the gas between the electrodes. An experiment was performed to show that the discharge takes place more readily, *i. e.*, at a lower potential between a pointed conductor and a flat plate when the plate is negative and the point positive. It was also shown that after a spark has passed, a lower potential is sufficient to cause a second discharge. Moreover, a gas which has been exposed to Röntgen, Cathode or Becquerel rays will break down more easily than gas which has not been exposed to such rays. Ultra-violet light falling on the negative terminal will decrease the insulating property of the gas.

"The character of the discharge between electrodes changes in a marked manner with the pressure of the gas. A set of vacuum tubes was shown in which the pressure varied from approximately 40 mm. to 1/1000 mm. With the highest pressure the discharge (obtained by means of an induction coil) was threadlike, changing as the pressure diminished to a ribbon, then a striated discharge, the color depending on the gas used. At pressures less than 1/1000 mm. the character of the discharge was entirely

altered. In place of the color previously obtained the glass seemed aglow with a greenish light, independent of the gas used.

"The phenomena connected with striated discharges are most interesting. There is a soft glow which moves over the surface of the cathode; next to the cathode there is a space which is comparatively free from luminosity—called the Crookes dark space. The distance from the cathode, through which this dark space stretches, increases as the exhaustion of the gas increases. Next to the dark space exists what is known as the negative glow. Its position is independent of the position of the positive terminal or anode, *i. e.*, if the anode is placed in a side tube, the negative glow does not bend round into this side tube. Beyond the negative column is the positive luminous column, consisting of alternate bright and dark bands, called striae, whose color depends on the nature of the gas. The positive column always moves with the anode, and takes the shortest path between the cathode and anode. As the rarefaction increases the striae gradually disappear, the Crookes dark space enlarges, and ultimately the tube itself glows with a phosphorescent light, whose color depends on the composition of the glass. Soda glass gives a green phosphorescence, lead glass a blue one. The position of the phosphorescent glow would indicate that something was being emitted normally from the cathode, and that the negative terminal or cathode is of particular importance in discharges at low pressure.

"On passing a discharge through a bent tube the green phosphorescence was excited only in the branch containing the negative terminal, the discharge from the cathode not being able to round the bend. With a tube in which a Maltese cross of platinum was placed directly opposite the negative terminal, phosphorescence was obtained outside the geometrical shadow only, when the discharge took place. On throwing down the screen, that part of the glass which had been protected glowed intensely. These rays from the cathode were named 'cathode rays' by Goldstein.

"The following properties of cathode rays were brought out experimentally: (1) They are propagated in straight lines; (2) produce heat by concentration; (3) cause fluorescence and phosphorescence; (4) are deflected by a magnet; (5) two streams of cathode rays repel each other. The exceedingly important property that the gas through which the cathode rays pass becomes a conductor through ionization was not shown experimentally.

"Until 1896 there were two theories of cathode rays. Crookes, as a result of some remarkable investigations, carried on by him during the period 1874-1879, concluded that the cathode rays consisted of very fine particles of matter, shot out normally from the cathode, which particles traveled in straight lines and caused phosphorescence, heat and chemical changes by their bombardment. The German scientists, on the other hand, believed the emanation to be a wave motion in the ether, the disturbance originating at the cathode. This latter hypothesis was somewhat strengthened through the discovery by Lenard (1893) of the existence of cathode

rays outside a vacuum tube, *i. e.*, in the air. Following a suggestion of Hertz, Lenard had a vacuum tube constructed with a hole opposite the cathode. This opening was closed by a thin piece of aluminum. Under the bombardment of cathode rays, rays of exactly the same properties were observed in the air outside the aluminum window. It was very difficult for the Germans to conceive of the passage of particles of matter through a solid, wnereas it was well known that thin films of metal are transparent tc ether disturbances. The wave hypothesis was abandoned, however, after the discoveries of Perrin and J. J. Thomson.

"Perrin discovered, in 1896, that the cathode rays carry a negative charge, and Thomson showed that the cathode rays may be deflected by a magnet. A little later Thomson, Kaufmann and others measured the size of the cathode particles and the magnitude of the negative charge which they carry. It was found that the magnitude of charge and mass of the particles were independent of the material of the electrodes and the nature of the gas. The mass of the cathode particle is equal to 1/1000 of the mass of the hydrogen atom, a fact of greatest importance in the theory of the constitution of matter."

A short statement was made regarding the history of the rays discovered by Professor Röntgen in 1895 and their relation to cathode rays. The Röntgen rays are produced where the cathode rays strike the glass tube. A better arrangement is to cause the cathode rays to fall on a piece of platinum which is either in connection with the earth or acts as an anode. The rays travel in straight lines, cause fluorescence, phosphorescence and chemical changes, ionization of gases, and pass through many substances which are opaque to cathode rays, and to ordinary light. It has been proven that the rays do not carry charges, and are not deflected by a magnet. It is probable that they are of the nature of wave disturbance in the ether.

The lecturer next spoke briefly on the so-called Becquerel rays, and by means of a sample of radium showed the radio-activity possessed by this substance in common with some other substances as uranium and thorium. The specimen was a layer of whitish substance about 1¼x¾ inch inclosed in a case, the covers of which contained lead or some other substance not easily penetrated by the rays. Dr. Wendell referred to the penetrating power of the rays. For instance, a person could not carry such a specimen in his pocket without noticing its effect on the skin, and he had demonstrated its power to affect a gold leaf electroscope through his body. He charged some pith balls with positive electricity and, holding the radium about two feet away, showed its effect in discharging the balls. The Becquerel rays are a mixture of Röntgen and cathode rays, as shown by their power to produce the effects of both kinds.

Reported by LYMAN C. NEWELL